RELATIVE EXERCISE INTENSITY, HEART RATE, OXYGEN CONSUMPTION, AND CALORIC EXPENDITURE WHEN EXERCISING ON VARIOUS NON-IMPACT CARDIO TRAINERS

Kirsten Hendrickson, B.S.

John P. Porcari, Ph.D.

Carl Foster, Ph.D.

Setting the pace since 1971

La Crosse Exercise and Health Program

University of Wisconsin – La Crosse

INTRODUCTION

Regular exercise and physical activity are beneficial for long-term health and well-being. The body responds to physical activity in ways that have significant positive effects on the cardiovascular, musculoskeletal, and respiratory systems. To promote and maintain health, the American College of Sports Medicine (ACSM) recommends that all healthy adults aged 18-65 years need a minimum of 30 minutes of moderate-intensity aerobic activity five days each week or vigorous-intensity aerobic activity for a minimum of 20 minutes on three days each week (1).

Physical activity also plays an important role in weight reduction and maintenance. Results from the National Health and Nutrition Examination Survey indicate that an estimated 61% of American adults are either overweight or obese (2). Specific guidelines from ACSM recommend that as part of a weight loss program, a minimum of 300 kilocalories should be expended during each exercise session for a minimum of three to five days per week (1).

There are many forms of aerobic activity that can be used to achieve the aforementioned benefits. However, the activity must be performed continuously, must use large muscle groups, and must be rhythmic in nature (1). Some traditional forms of aerobic activity include walking, jogging, biking, swimming, and aerobic dance.

Over the past several years elliptical machines have become an increasingly popular way to achieve cardiorespiratory fitness and manage weight. The elliptical pattern of foot movement results in less impact on the joints than treadmill jogging, while eliciting similar heart rate and oxygen consumption values (3,4). Submaximal responses to exercising on an elliptical trainer result in relative exercise intensities that are within ACSM guidelines and achieved VO_2max values are similar to those achieved on a treadmill (4-6). Additional research indicates that training on elliptical machines produce similar physiological improvements when compared to treadmill running and stair climbing when volume and intensity are equivalent (7).

As more non-impact exercise machines come onto the market, there is a need to compare the responses between machines to determine which one might be most beneficial. Therefore, the purpose of this study was to compare the relative exercise intensity and the caloric expenditure when individuals exercised on a Cybex Arc Trainer (ARC), a Precor Adaptive Motion Trainer (AMT), and a Precor EFX 546i elliptical trainer (EFX) at a self-selected intensity.

METHODS

Subjects

Subjects consisted of 16 apparently healthy adults between the ages of 22-30 years who were all regular exercisers. Each participant provided written informed consent before beginning the study. Approval from the University of Wisconsin-La Crosse Institutional Review Board for the Protection of Human Subjects was obtained prior to beginning this study.

Procedures

Subjects initially completed a maximal exercise test on a motor-driven treadmill to determine their aerobic capacity (VO_2max) and maximal heart rate (HRmax). During the test, subjects were connected to an AEI Technologies Moxus Modular VO_2 System to analyze expired gases and a Polar heart rate monitor was used to record heart rate. The Borg 6-20 scale was used to measure ratings of perceived exertion (RPE). The test began at a low workload and progressively increased in difficulty until the subject reached volitional exhaustion.

Following the maximal test, subjects completed three, 45-minute practice sessions (15 minutes on each modality) to become familiar with the proper use of each machine. Once the practice sessions were completed, subjects performed a 30-minute workout on each machine in random order. Each workout was completed on a separate day with a minimum of one day of rest between workouts. Each workout was conducted at a self-selected pace. Variables measured included VO_2, HR, and RPE. Caloric expenditure was calculated from the VO_2 data and O_2 pulse values (ml/beat) were calculated from the VO_2 and HR data.

These measurements were taken at 5-minute intervals during each 30-minute testing session. All testing and practice sessions were conducted in the Human Performance Laboratory in Mitchell Hall.

Statistical Analysis

Standard descriptive statistics were used to characterize the study population. For each variable, responses between modalities were compared using a one-way ANOVA with repeated measures. When there was a significant F ratio, a Fisher's LSD post-hoc test was used to isolate pairwise comparisons. Alpha was set at .05 to achieve statistical significance.

RESULTS

The descriptive characteristics of the subjects are displayed in Table 1. Subjects ranged in age from 22-30 years of age and were considered highly fit based upon normative data (11).

Table 1. Descriptive characteristics of the subjects (N=16).

	Males (n=4) X ± SD	Females (n=12) X ± SD
Age (years)	22.5 ± .58	24.0 ± 2.10
Height (cms)	182.2 ± 6.14	166.7 ± 6.63
Weight (kg)	85.4 ± 10.9	61.0 ± 7.33
VO_2 max (ml/kg/min)	51.2 ± 8.6	46.4 ± 5.8
HR max (bpm)	193 ± 11.7	185 ± 10.2

Data relative to exercising on the AMT, ARC, and EFX are presented in Table 2. Males and females had similar physiological responses, thus only aggregate data are provided. Exercise heart rates on the ARC and the AMT were significantly higher than on the EFX. Caloric expenditure (Kcals/min and total Kcals) was significantly higher on the ARC compared to the AMT (9%) and the EFX (16%). Oxygen consumption was also 9% higher on the ARC compared to the AMT and 16% higher than on the EFX. However, the difference between the ARC and the AMT was not statistically significant (p=.068). Calculated oxygen pulse values were also significantly higher on the ARC compared to the AMT and the EFX. The self-selected exercise intensities used in the present study elicited similar RPE responses for all three exercise modalities.

Table 2. A Comparison of the Physiological Responses to Exercising on a Precor Adaptive Motion Trainer (AMT), a Cybex Arc Trainer (ARC), and a PRECOR EFX 546i (EFX).

	AMT X ± SD	ARC X ± SD	EFX X ± SD
HR	153 ± 15.9[a]	152 ± 14.4[a]	143 ± 16.7
%HR	82 ± 7.9[a]	81 ± 8.6[a]	76 ± 8.4
VO_2	29.4 ± 5.5	32.1 ± 7.7[a]	27.6 ± 6.0
$\%VO_2$	62 ± 10.2	67 ± 12.8[a]	58 ± 9.4
RPE	13.7 ± 1.2	13.6 ± 1.3	13.2 ± 1.4
Kcals/min	9.9 ± 3.2	10.8 ± 3.5[ab]	9.3 ± 3.4
Total Kcals	298 ± 95.3	325 ± 104.7[ab]	279 ± 101.5
O_2 pulse	13.0 ± 3.7	14.5 ± 5.4[ab]	12.9 ± 3.5

[a] Significantly greater than EFX ($p<0.05$)
[b] Significantly greater than AMT ($p<0.05$)

DISCUSSION

The main purpose of this study was to compare the relative exercise intensity and caloric expenditure when individuals exercised on a Cybex Arc Trainer, a Precor AMT, and a Precor EFX 546i elliptical trainer at a self-selected pace. Knowledge of which non-impact machine elicits the greatest physiological response is beneficial to users who wish to improve cardiovascular function and manage weight.

According to ACSM (1), HR during exercise should be between 64-94% of maximum HR in order for individuals to gain a cardiorespiratory benefit. The results of this study found that heart rates fell within these guidelines for all three modalities, averaging 82%, 81%, and 76% of HRmax for the AMT, ARC, and EFX, respectively. ACSM also recommends that VO_2 should be between 40-85% of VO_2max in order to improve aerobic capacity. This study found that VO_2 levels were also within ACSM guidelines for all three modalities, averaging 62%, 67%, and 58% of VO_2max for the AMT, ARC, and EFX, respectively. Thus, all three machines elicited physiological responses that fell within the ACSM guidelines for exercise training.

Although individuals were able to meet ACSM guidelines on all three machines, there were differences between modalities. Exercise heart rates on the ARC and the AMT were higher than on the EFX. In addition, oxygen consumption and caloric expenditure (Kcals/min and total Kcals) were 9% higher on the ARC when compared to the AMT and 16% higher than on the EFX. Previous research has suggested that oxygen uptake and caloric expenditure are increased with the utilization of greater amounts of muscle mass (6-8). On the EFX, the arms are not included in the workout, as it is a lower body only elliptical machine. Thus, exercise intensity was expected to be lower compared to the other two machines. The AMT does include arm movement; however, the range of motion is smaller than on the ARC. It was felt that the greater range of motion on the ARC allowed the users to get greater involvement of the back muscles, which helped to increase oxygen cost and caloric expenditure (9).

Oxygen pulse values were also significantly higher on the ARC compared to the other two modalities. Higher O_2 pulse values reflect a greater delivery of oxygen to the working muscles with each heart beat and indicate that the ARC is more "aerobic" compared to the other two machines. Lower O_2 pulse values indicate that a machine is less efficient in terms of the body's ability to deliver oxygen to the tissues and indicate that a higher pressor response may be occurring (8). Because the AMT can be used more like a stepper, it was hypothesized that the quadriceps and buttocks were working at a relatively high percentage of their maximal strength (MVIC). This would invoke more of a pressor response and artificially elevate HR values relative to oxygen consumption.

CONCLUSION

Based upon the results of this study, it would appear that exercising on the ARC trainer provides the best overall workout compared to the AMT and the EFX, and would result in the greatest increase in aerobic capacity and reduction in body weight in the shortest period of time.

REFERENCES

1. Haskell, W.L., Lee, I.M., Pate, R.R., Powell, K.E., Blair, S.N., Franklin, B.A., Macera, C.A., Heath, G.W., Thompson, P.D., & Bauman, A. Physical Activity and Public Health: Updated Recommendation for Adults from the American College of Sports Medicine and the American Heart Association. *Medicine and Science in Sports and Exercise,* 39 (8): 1423-1434, 2007.

2. U.S. Department of Health and Human Services. *Physical Activity and Health: A Report of the Surgeon General.* Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion; 1996.

3. Porcari, J.P., Foster, C., & Schneider, P. Exercise response to elliptical trainers. *Fitness* Management, August: 50-53, 2000.

4. Spranger L. A comparison of the physiological responses to exercise on five different upper and lower body ergometers. Masters thesis in Adult Fitness/Cardiac Rehabilitation, University of Wisconsin-La Crosse, 1998.

5. Sweitzer, M.L., Kravitz, L., Weingart, H.M., Dalleck, L.C., Chitwood, L.F., & Dahl, E. The cardiopulmonary responses of elliptical crosstraining versus treadmill walking in CAD patients. *Journal of Exercise Physiology,* 5 (4): 11-15, 2002.

6. Dalleck, L.C., Kravitz, L., Robergs, A. Maximal exercise testing using the elliptical cross-trainer and treadmill. *Journal of Exercise Physiology,* 7 (3): 94-101, 2004.

7. Egana, M. & Donne, B. Physiological changes following a 12-week gym based stair-climbing, elliptical trainer, and treadmill running program in females. *Journal of Sports Medicine in Physical Fitness,* 44(2): 141-6, 2004.

8. Astrand, P.O., Rodahl, K., Dahl, H. A., Stromme, S. B. *Textbook of Work Physiology*. 4: 247-248, 2003.

9. Bergh, U., I.-L. Kanstrup, & Ekblom, B. Maximal Oxygen uptake during exercise with various combinations of arm and leg work. *Journal of Applied Physiology,* 41:191-196, 1976.

10. Stenburg, J., Ekblom, B., Royce, J., & Saltin, B. Hemodynamic response to work with different muscle groups in sitting and supine position. *Journal of Applied Physiology,* 22:61-70.

11. ACSM's Guidelines for exercise testing and prescription (7th Edition). Lippincott Williams & Wilkins: Philadelphia, 2006.